APRIL 30, 1984

CHEMICAL & ENGINEERING

NEWS

Major elastomers recover steadily
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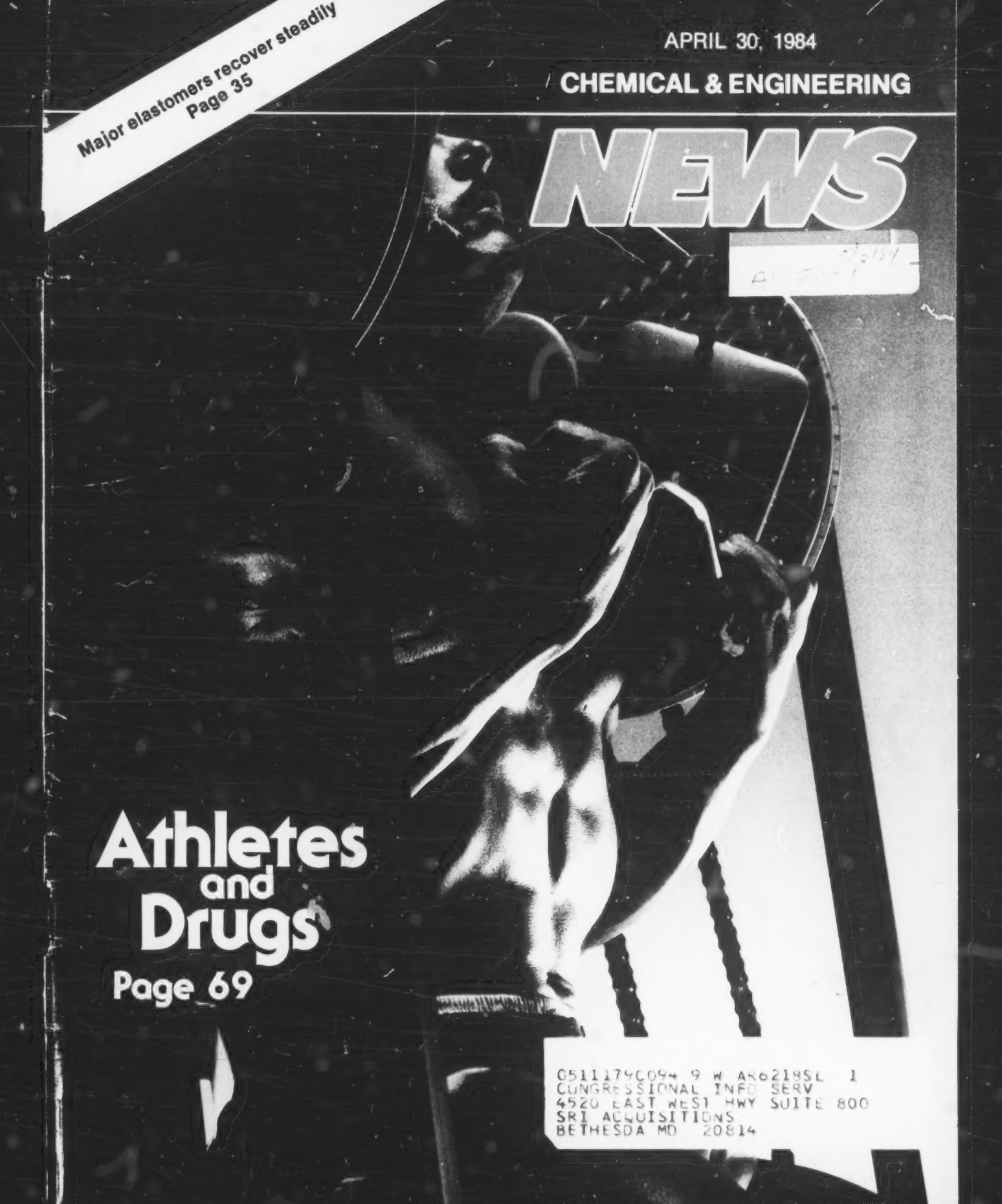

Athletes and Drugs

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CHEMICAL & ENGINEERING NEWS

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APRIL 30, 1984

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ACS News

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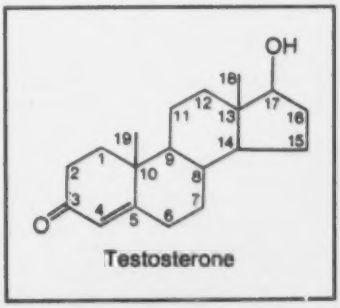


Testosterone

Special Report

Value of drugs in enhancing athletic performance is debatable as is the danger; techniques for their detection will be on hand at the Olympics. **Page 69**

W. R. Grace photo

Elastomers Finally Recover Growth

Bruce F. Greek, C&EN Houston

For much of the past five years, world markets for elastomers could not live up to elastomers' definition—materials that recover shape after a deforming force—but that may be changing. Although battered in both markets and raw materials by sharp hikes in oil prices, rubber is now slowly regaining its old resilience. Steady growth ahead is the view of many industry analysts.

Of course, steady growth for rubber is not on the order of growth in home video and computers. A welcome clip for the rest of the 1980s for stately elastomers would be just 3% per year, and even that rate draws considerable argument.

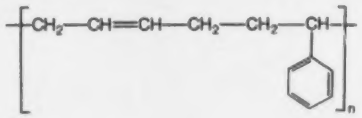
Remaining pessimism in some quarters is understandable. Some of the aftermath of elastomers' drubbing since 1979 isn't over. For example, later this year, plants at Borger, Tex., used to make polybutadiene and styrene-butadiene rubber (SBR), will be shut down. Phillips Chemical owns the SBR plant and operates the polybutadiene plant, which it owns with Armstrong Rubber and General Tire & Rubber. These plants have a nameplate capacity of 90,000 metric tons of SBR and 60,000 metric tons of polybutadiene.

But some changes are forecast for the future. Consumption of synthetic rubber will be rising from the nadir of recent times reached in 1982. During the next five years, consumption of synthetic rubber will increase at an average of 3.3% annually, according to forecasts released earlier this month by the International Institute of Synthetic Rubber Producers (IISRP).

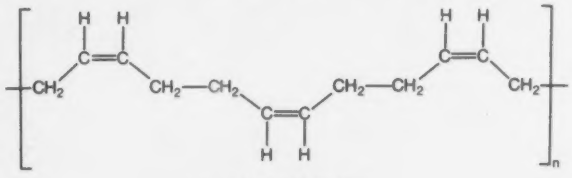
This year global consumption (excluding communist nations) of new synthetic rubber will rise to more than 5.1 million metric tons from about 5.0 million in 1983. By 1988, new synthetic rubber consumption will increase to more than 5.6 million metric tons, according

Butadiene and isoprene dominate starting materials for the major elastomers

Styrene-butadiene rubber (SBR) makes up the majority of synthetic rubber production, although its share is declining. Different polymerization technologies and modifications to the basic polymer result in many molecular forms with many different properties.

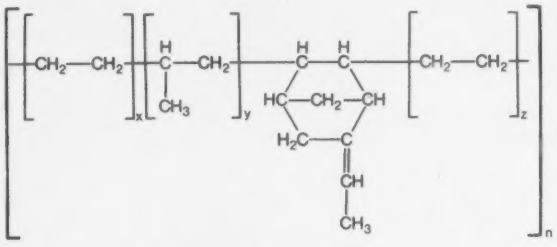


Polybutadiene rubber for most commercial uses is made with the maximum content of *cis*-1,4-polybutadiene. The volume of the transconfiguration is so small that it is considered a specialty rubber. Even much smaller in volume are the 1,2-polymers, which can be made in several forms.

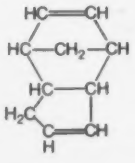


cis-1,4-Polybutadiene

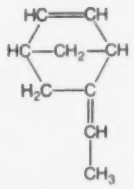
Ethylene-propylene-terpolymer rubber, sometimes called ethylene-propylene-diene monomer (EPDM), contains large numbers of ethylene and propylene groups with an occasional nonconjugated diene. Most commonly used diene is ethylidene norbornene.



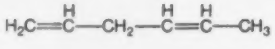
Nonconjugated dienes used in EPDM



Dicyclopentadiene



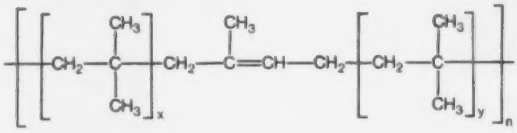
Ethylidene norbornene



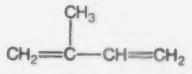
1,4-Hexadiene

a Polymer contains many arrangements of starting material.

Butyl rubber, a copolymer of isobutylene and isoprene in its most common form, contains a large number of butyl groups relative to isoprene groups. Changing the ratio changes properties. Frequently the polymer is halogenated to give elastomers of desired properties.

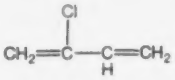


Polyisoprene rubber is similar to natural rubber in that it is high in *cis*-1,4-polyisoprene. Polymer compositions of different properties vary with catalysts and reaction conditions.



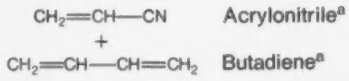
Isoprene[a] (2-methyl-1,3-butadiene)

Polychloroprene rubber (neoprene) results from 1,4 addition polymerization. The polymer contains some isomers, depending on polymerization conditions.

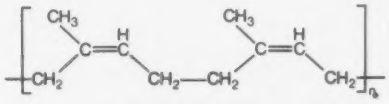


Chloroprene[a] (2-chloro-1,3-butadiene)

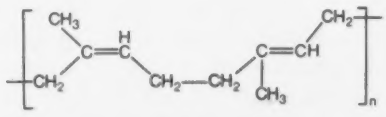
Nitrile rubber is a copolymer of acrylonitrile and butadiene with compositions ranging from as low as 15% acrylonitrile to about 45%.



Natural rubber consists of more than 98% *cis*-1,4-polyisoprene, plus a small amount of *trans*-1,4-polyisoprene, and tiny amounts of many other compounds, some of which are yet unidentified.



cis-1,4-Polyisoprene



trans-1,4-Polyisoprene

Global synthetic rubber production has trended downward

Thousands of metric tons	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Styrene-butadiene										
Solid	2254	2467	2583	2915	2936	2950	2750	2577	2877	3269
Latex	253	288	310	425	405	379	386	237	246	247
Polybutadiene	832	898	910	981	919	895	784	699	757	783
Polyisoprene	128	167	221	236	223	208	210	196	220	290
Ethylene-propylene	279	341	316	348	310	290	239	179	198	180
Polychloroprene	322	317	314	354	328	319	311	289	313	329
Butyl	374	406	415	441	415	386	353	316	336	349
Nitrile	182	199	207	236	206	190	181	138	195	201
Acrylates	25	31	32	32	30	29	29	28	—	—
Other	59	73	70	80	73	60	48	36	72	74
TOTAL	4708	5187	5378	6048	5847	5706	5291	4695	5214	5722

Note: Production of communist countries not included. Source: International Institute of Synthetic Rubber Producers

to IISRP's Worldwide Statistical Committee. These estimates do not include carboxylated SBR latex.

Consumption of natural rubber also is forecast to increase but at a bit slower rate. IISRP estimates that natural rubber consumption in noncommunist countries this year will rise to 3.17 million metric tons from 3.11 million in 1983. By 1988, natural rubber consumption is projected at 3.47 million metric tons.

Total new rubber consumption in the world excluding communist countries will amount to more than 8.3 million metric tons in 1984 and 9.1 million metric tons in 1988. The fraction of rubber made synthetically will hold at close to 62%.

Rubber consumption in communist countries will consist of a higher and slowly rising fraction of synthetic rubber. In 1984, total new rubber consumption will be more than 3.4 million metric tons, according to IISRP estimates. Of that total, about 78% will be synthetic elastomers. By 1988, IISRP projects that consumption will climb to 3.8 million metric tons, with synthetics accounting for almost 80% of the total.

Of the communist countries, those in Eastern Europe consume the highest relative portion of synthetic rubber, compared to total rubber use. About 86% of 2.92 million metric tons of rubber consumed there this year will be synthetic. That percentage will rise to 88% in 1988 when total new rubber consumption is projected to be 3.2 million metric tons.

As might be expected, however, for China and other Asian communist countries (grouped together for the purpose of statistical analysis), the synthetic fraction of total rubber consumption is low. In 1984, IISRP estimates that about 36% of a little more than 500,000 metric tons of total rubber consumption in these countries will be synthetic. By 1988, the synthetic fraction will rise to almost 40% of total consumption of 630,000 metric tons.

These general small increases in worldwide rubber consumption are

World synthetic rubber capacity is dropping . . .

Thousands of metric tons	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Western Europe, Middle East, Africa	3162	3139	3058	2910	2781	2696	2705	2632	2528	2520
North America	3099	3395	3437	3320	3271	3323	3426	3355	3315	3229
Latin America	511	515	517	438	396	389	378	388	297	288
Asia & Oceania	1938	1895	1866	1711	1696	1567	1512	1486	1585	1440
TOTAL	8710	8944	8878	8379	8144	7975	8021	7861	7725	7477

. . . and styrene-butadiene rubber accounts for most of the decline

Thousands of metric tons	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975
Styrene-butadiene	5146	5345	5448	5180	5019	4951	4991	4890	4782	4635
Polybutadiene	1339	1310	1261	1191	1176	1146	1124	1036	1096	1059
Polyisoprene	289	397	297	289	289	281	344	379	359	353
Ethylene-propylene	502	498	476	428	428	385	385	391	356	359
Butyl	583	539	533	446	498	493	466	465	429	396
Polychloroprene	431	422	433	521	416	405	405	400	389	373
Nitrile	420	428	430	428	316	314	306	300	311	302
TOTAL	8710	8944	8878	8379	8144	7975	8021	7861	7725	7477

Note: Figures include latexes, but exclude specialty rubbers; noncommunist country data only. Source: International Institute of Synthetic Rubber Producers

Glossary of rubber terms

Acrylate rubber. A class of elastomers based on acrylate esters.

Atactic polymer. A polymer type in which substituents on the polymer chain are arranged randomly. Opposite of isotactic polymer.

Block copolymer. A polymer consisting of two or more separate chain sequences, each with properties similar to those that a homopolymer would have if it were the chain alone.

Carbon black. Powdered elemental carbon used to reinforce elastomers. Differences in manufacturing give carbon blacks with varying properties in the compounded elastomer.

Coagulation. The process of converting dispersed particles of latexes into large coherent particles of elastomer. Coagulation is caused by both physical and chemical changes in the latex.

Crystallinity. Degree of orientation of polymer molecules in repeating patterns; influences properties such as stiffness and heat resistance.

Elastomer. A polymeric material that can recover its shape after removal of a deforming force. In general, this term means a synthetic polymer. By constrast, the term rubber usually means the natural product.

Emulsion polymerization. A process in which monomer particles are emulsified with a soap in water and polymerized.

Gross rubber. The total weight of salable product, including elastomer, carbon black, extender oils, and other compounding materials.

Gutta-percha. A type of natural rubber which is high in *trans*-polyisoprene; by contrast, normal Hevea-type natural rubber is high in *cis*-polyisoprene.

Hevea. The most common and largest-volume natural rubber tree genus from which the latex is taken.

Isotactic polymer. Polymer structure with repeating asymmetric atoms. Opposite of atactic.

Latex. An aqueous colloidal emulsion of any kind of rubber or plastic.

Masterbatch. The mixture of elastomer or natural rubber and other materials such as carbon black and fillers used to make the compounded rubber for final fabrication.

Natural rubber. Rubber formed in a plant, most often the tree *Hevea brasiliensis*.

New rubber. All rubber, synthetic or natural, produced or used for the first time; excludes all reclaimed or scrap rubber.

Oil content. Hydrocarbon oils added to polymer as an extender or processing aid.

Plantation rubber. Crude natural rubber from cultivated rubber trees in contrast to rubber from wild trees.

Ribbed smoked sheets. Plantation natural rubber sheets that have been passed through a ribbing mill, washed, and then hung on racks in a smokehouse.

Thermoplastic rubber. An elastomer that repeatedly can be softened by heating and hardened by cooling; not vulcanized but shows properties similar to vulanized rubber.

Vulcanization. Process for crosslinking polymer chains, causing an elastomer to become less plastic and more elastic. Often restricted to crosslinking with sulfur; by contrast, the term curing covers other crosslinking methods.

Sources: B. F. Goodrich, International Institute of Synthetic Rubber Producers

based on the assumption that no large increase in world oil prices will occur. If world oil prices should increase by large amounts for whatever reason, then new rubber consumption likely will decline again, as it did following the large increases in oil prices in 1974 and in 1979.

The impact oil price increases have had on rubber consumption has been severe. Excluding local production in communist countries, global synthetic rubber production dropped 4% in 1974 from the previous peak in 1973 and nearly 23% in 1975 from the 1973 peak.

Recovery in synthetic rubber production began in 1976 and continued through 1979 when total production in noncommunist countries reached more than 6 million metric tons. Then another slide began when production dropped 11% in 1980. The slide continued through 1982 with production in that year down more than 22% from 1979.

For the previous 18 years (1956 to 1973), synthetic rubber production had grown at an annual rate of 9.7%. This growth had resulted from three major factors. The Korean conflict had caused the price of natural rubber to more than double in less than six months, making it clear that natural rubber could very quickly become an unstable commodity. In 1949, the development of "cold" (4 to 5 °C) polymerization technology led to rubbers with much higher strength and recovery properties. In 1950, oil extension of synthetic rubber was developed, which greatly improved costs of using it.

Then in 1955, the U.S. government sold some 25 plants built during World War II to make monomers and synthetic rubber. The law covering the disposal also removed all restraints from independent research and development and permitted exportation of synthetic elastomers and technology, which had been severely limited under government ownership.

These actions radically changed the world rubber business. Good quality synthetic elastomers became available on a worldwide basis. Rubber demand, restricted because of limited availability of natural rubber, boomed. In the years 1956–73, worldwide demand for all types of rubber tripled.

Rapid expansions of capacity to make synthetic elastomers took place in many parts of the world. Rubber demand outside the U.S. increased even faster than U.S. demand. The U.S. share of the world market for rubber dropped from 42% in 1956 to about 27% in 1974.

Then came the oil price increases. The results are well known—inflation, smaller cars with smaller tires, less driving, and a big decline in U.S. car production. Coincidentally, but partly as a result of the oil price increases, much wider acceptance of radial tires occurred. All these

Both total rubber consumption and fraction supplied by synthetics will rebound over next five years

Thousands of metric tons	1982	1983	1984	1988
Noncommunist countries				
Synthetic	4,815	4,994	5,139	5,630
Natural	2,980	3,110	3,169	3,469
Total	7,795	8,104	8,308	9,099
% Synthetic	61.8%	61.6%	61.9%	61.9%
Communist countries				
Synthetic	2,556	2,600	2,684	3,048
Natural	726	741	752	778
Total	3,282	3,341	3,436	3,826
% Synthetic	77.9%	77.8%	78.1%	79.7%
Total world				
Synthetic	7,371	7,594	7,823	8,678
Natural	3,706	3,851	3,921	4,247
Total	11,077	11,445	11,744	12,925
% Synthetic	66.5%	66.4%	66.6%	67.1%

Source: International Institute of Synthetic Rubber Producers

factors combined to reduce rubber demand further, especially after the second big oil price increase of 1979.

The correlation of rubber consumption and motor fuel consumption also developed clearly as the 1980s began. U.S. rubber consumption in tires fell beginning in 1974; it recovered to a new high in 1977 and fell again through 1982. By 1982, rubber consumption in tires had declined to slightly less than 1.4 million metric tons, down 33% from the nearly 2.1 million metric tons consumed in tires and tire products in 1977.

Rubber consumption in tires was about 1.4 million metric tons in 1983

In the major Western European countries, rubber consumption in tires fell more slowly and to a smaller degree, dropping 16% from about 1 million metric tons in 1977.

In Japan the situation was different, with consumption rising through 1980 after small declines in 1974 and 1975. By 1982, however, demand was off almost 10%.

The drop in U.S. consumption of rubber in tires and tire products between 1973 and 1983 shows why the rubber business became so difficult. Rubber consumption in tires in 1983 was down 628,000 metric tons from 2.022 million metric tons in 1973. Of the total decline, 546,000 metric tons were synthetic elastomers. (Natural rubber use declined fractionally less because of the shift to radial tires, which use more natural rubber.) Passenger tire production dropped from 202 million in 1973 to 168 million last year. Also, during the same time, the average weight of a passenger car tire declined, from 13 kg in 1973 to 9.8 kg in 1983. Commercial tire production also fell 8% over this period, whereas average weight rose 1%. The loss in rubber consumption in tires because of downsizing of tires, IISRP estimates, amounts to 266,000 metric tons. The loss as a result of fewer tires amounts to another 222,000 metric tons. Commercial and other tires and miscellaneous uses account for the remaining 140,000 metric tons of decline.

Now, however, the worst may be over for the consumption loss in tires. Both the downsizing of tires used on U.S. cars and the switch to radial tires appear to be about complete. The tire sizes used on European and Japanese cars also are expected to be relatively stable.

Therefore, according to industry analysts, the amount of rubber used in tires will relate most closely to the number of tires being produced. The number of tires being produced, in turn, will relate to car production. It also will relate, but less precisely, to average age of cars on the road. A rising age of the car population would tend to mean more sales of replacement tires. But the correlation isn't direct because of the rise in use of radial tires, which offer 50 to 100% longer tread life than previous tire types. In addition to longer tread life, tire makers have improved other properties that lengthen the lives of tires, such as better resistance to ozone.

Other factors are affecting tire life and, in turn, the eventual amount of rubber used in making tires. Front-wheel-drive cars as well as lighter cars also are improving average tire tread life.

The emphasis on fuel economy also has a growing impact on tire life. Fuel economy can be improved by reducing the rolling resistance of tires. One way to achieve a quick gain in this area is to raise tire inflation pressures. Generally, an increased inflation pressure within reason also will improve tire life significantly.

Tire makers continue to face the problem of making the correct tradeoffs between such factors as ride quality, handling, reduced rolling resistance, and cost desired by auto makers and tire life, trouble-free use, and cost wanted by the car-buying public. Besides improvements in

A history of rubber

Synthetic elastomers started as did most other synthetic products because of chemists' interest in natural products. The resulting high-molecular-weight elastomers are distinctly different from natural rubber, although with some closely duplicated properties.

Purists still like to distinguish between natural and synthetic rubber, reserving the word "rubber" only for the natural product tapped from trees and using "synthetic elastomers" for polymers made in chemical plants.

Europeans began to experiment with natural rubber in the early 16th century after Spaniards brought it back from the American Indians. By the 19th century, natural rubber's properties were known widely, and a limited amount of rubber fabrication was being done. Then development followed rapidly with these important milestones:

1839. Charles Goodyear in the U.S. discovered vulcanization.

1876. Henry Wickham smuggled 70,000 seeds of a rubber tree, *Hevea brasiliensis*, to London where enough germinated to enable later plantations of cultivated rubber trees in Ceylon.

1888. John Boyd Dunlop in Belfast patented a pneumatic tire.

1900. Automobile production became significant and tire demand rose fast.

1909. Fritz Hofmann in Germany received first synthetic rubber patent.

1910. Natural rubber prices rose to $3.20 per lb spurring interest in developing synthetic elastomers.

1916. Methyl rubber made from dimethylbutadiene reached production rate of 150 tons a month in Germany.

1929. Synthetic elastomers similar to modern styrene-butadiene and nitrile rubbers were developed in Germany.

1932. Natural rubber prices fell to all-time low of 3.5 cents per lb.

1939. German synthetic elastomer capacity reached 150,000 tons per year; Soviet production reached 90,000 tons per year.

1945. U.S. synthetic rubber production exceeded 700,000 tons.

1950. Rubber demand rose to level where natural rubber clearly could not supply all needs; synthetic elastomer capacity was expanded in many parts of the world.

1979. Synthetic elastomer production in noncommunist countries reached peak of 6.167 million metric tons.

physical design of tires, tire makers are making chemical improvements in their synthetic elastomers to help achieve desirable properties in tires.

All of these improvements unfortunately offer scant hope to rubber producers. Opinion varies widely on the longer-term outlook for U.S. consumption of elastomers in tires. One view is that, on average, for the rest of the 1980s the number of tires produced will increase at a 2% annual rate at best. But because of the improvements in tires and their use, changes in tire size and car weights, and production of more radial commercial tires, the gain in use of elastomers in tires will be tiny if any. In fact, there's a chance that use of elastomers in U.S.-made tires will decline slightly over the next few years.

Part of the problem of lower U.S. tire and elastomer output comes from the rising share of imported cars sold in the U.S. in recent years. Capacity to make rubber and tires has been reduced to about the demand level, with further reductions in demand leading to the plant shutdowns exemplified by those planned for this year by Phillips and its partners.

A more optimistic view holds that synthetic rubber demand will grow at about the same rate as gross national product, possibly higher because of the more rapid growth of those rubbers, such as ethylene-propylene-diene monomer (EPDM), that go predominately into nontire uses. Tire uses in developing countries could pull along SBR, too, as demand for automobiles and other vehicles in those countries expands more rapidly than in developed countries during the next two decades or so.

IISRP forecasts widely varying growth rates for synthetic rubber consumption in various regions. For example, the annual average growth rate forecast for North America for the next five years is about 2.4%. For Western Europe, Africa, and the Middle East, the rate is about 1.7%. For Asia and Oceania, the rate is about 3.3%. But for Latin America, including Mexico, the rate jumps to 7%, even though the base is small.

U.S. synthetic rubber production is up from recession but not nearly to previous highs

Thousands of metric tons	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Styrene-butadiene	905	879	1032	1074	1378	1395	1395	1333	1179	1466
Polybutadiene	333	268	342	311	397	378	361	353	290	310
Ethylene-propylene	175	123	178	145	178	174	158	130	84	126
Polychloroprene	115	119	143	151	183	181	165	165	144	183
Nitrile	55	45	66	63	75	73	70	73	55	88
Other*	396	301	373	327	319	379	334	305	229	406
TOTAL	1979	1835	2134	2071	2528	2580	2483	2359	1981	2559

a Includes such elastomers as polyisoprene, butyl, silicone, and urethane rubbers. Sources: Department of Commerce, industry sources

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Synthetic elastomer production in the industrialized areas of Western Europe, of the Middle East and Africa; of North America; and of the noncommunist areas of Asia and Oceania all ran well below profitable levels in 1982. Only Latin America, including Mexico, had a good operating rate, but the capacity total there is small.

Capacity utilization ranged from 54% in Europe to 83% in Latin America. It's likely that more plants will be shut down and that capacity in the noncommunist areas is sufficient to meet demand for synthetic elastomers through this decade.

Worldwide capacity to make synthetic elastomers, excluding communist countries, continued to rise until the recent recession made its impact on rubber demand clearly felt. As might be expected from the decline in rubber used in making tires, the workhorse polymer SBR took the brunt of the decline. Of the decline in consumption in the U.S. of the amount of rubber going into tires of some 600,000 metric tons from 1973 to 1982, more than 85% was in synthetic rubber. Of that, 75%, or more than 400,000 metric tons, was SBR.

In 1983, total estimated SBR consumption (both solid and latex but excluding carboxylated latex) in noncommunist countries rose a bit more than 100,000 metric tons to about 2.65 million metric tons. In 1984, consumption likely will be up another 100,000 metric tons, according to IISRP.

In the U.S., as in other industrialized areas, consumption of SBR has been trending toward maturity. Analysis of consumption growth of all synthetic rubber by Shell International Chemical indicates that SBR growth will be close to that of general industrial activity. Since EPDM and others, especially the specialty rubbers, are forecast to have higher growth rates than that of industrial activity, growth of rubbers such as SBR and polybutadiene could be below that of gross national product in industrialized areas.

The nontire uses of SBR could grow at a higher rate than tire use, but competition from other elastomers hinders even this growth.

Tires take 65% of rubber in North America

Rubber type	Percentage use in tires
Styrene-butadiene	74.1%
Latex	4.1
Polybutadiene	85.0
Polyisoprene	64.9
Ethylene-propylene	10.6
Polychloroprene	1.1
Butyl	80.0
Nitrile	0.8
Other	6.1
TOTAL SYNTHETIC	60.5%
Natural rubber	75.7
TOTAL RUBBER	64.8%

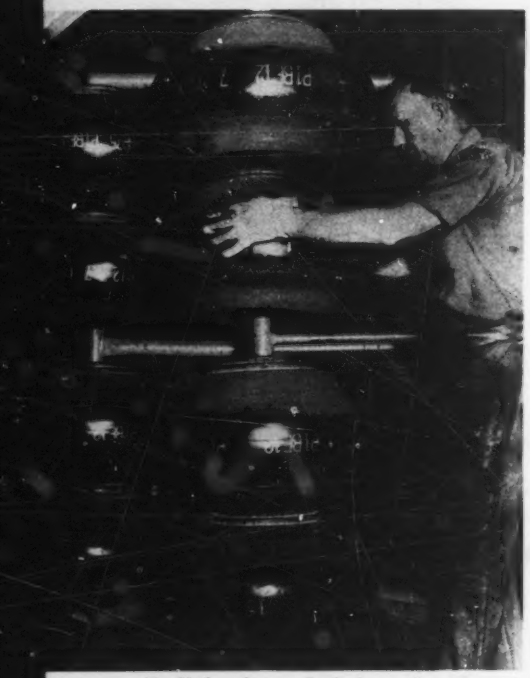
Source: International Institute of Synthetic Rubber Producers

Much SBR is blended with other elastomers to get better properties in the fabricated product. Cost of SBR keeps it in a favored position even as other materials impart somewhat better properties. By holding down price of the rubber, producers cover their cash costs of making it, but get nothing to put into development of better polymers.

The nontire uses of SBR are not expected to increase very fast because of the competition. With a significant fraction, about 10%, also going into automotive uses, automobile production influences these uses as well. This year with improved auto production, the nontire uses also could be up strongly. However, long term, the outlook is for growth of about 3%, better than that for tire use, but still not enough to help SBR much.

And it's still possible that more SBR plants may be shut down. Currently, American Synthetic Rubber's plant is not operating, but it has not been scrapped. By the end of this year, the only plants operating will be either directly owned by tire makers or closely related to a tire maker. Most of them likely will continue operating, although parts or trains could be shut down during periods of recession if rubber demand should decline. Considerable flexibility exists in the larger plants to reduce operations and save costs in this way.

The state of affairs for polybutadiene is similar in many ways to that



Radials, shown here in early stage of production, dominate the tire market

for SBR. Both, for example, have a predominate use in tires. More of polybutadiene's total use goes for tires, in fact, than with SBR; some 85% of North America's use of polybutadiene last year went to tires and tire products. Both elastomers are affected by the plant shutdowns at Borger. And both are likely to have relatively low growth in the near term because of the changes in tire life and size.

Global polybutadiene capacity, excluding communist countries, has continued to rise slowly since 1975 and reached about 1.3 million metric tons per year in 1982. Further capacity increases are in doubt for some time because of the current overcapacity and prospects for very slow growth in consumption. A decline in capacity temporarily may result because of the shutdown of the Borger plant. Small expansions have been disclosed in the past two years, but the recession may have slowed them.

To some extent polybutadiene hurt SBR consumption following its commercial introduction in the U.S. in 1961. Polybutadiene can provide better tread wear and rolling resistance properties in tires than SBR. It also has somewhat better properties of flexibility and resistance to heat buildup and aging.

Following the introduction of polybutadiene, consumption built up rapidly. By the fourth year of production, consumption of this rubber had reached 100,000 metric tons and by the eighth year, 200,000 metric tons. Use topped 400,000 metric tons in 1977 and has fallen some since then, with intermittent increases depending on economic conditions. In 1983, U.S. production rose more than 15% from 1982 to 333,000 metric tons.

The outlook for polybutadiene is about the same as that of SBR—good growth in years of economic recovery and declines in production during recessions. The average growth forecast over the long term, because of tire production and tire life, could be the same as for GNP or possibly even less.

Butyl rubber and polyisoprene rubber are other major volume synthetic elastomers going into tires and tire products. Currently there is only one producer of each in the U.S. Exxon Chemical makes butyl rubber at Baytown, Tex., and Baton Rouge. Goodyear Tire & Rubber makes polyisoprene at Beaumont, Tex. Production data for these two elastomers are not available other than in the "other" category for U.S. elastomer production.

Worldwide (excluding communist countries) consumption figures for butyl and polyisoprene rubber have been reported in the past by IISRP. These data for years up to 1982 show the typical peak in consumption in 1979 and a subsequent decline because of the world recession. However, more recent data are not available. Again, because their major use is in tires, the growth outlook for these two elastomers is similar to or less than that for GNP.

Nontire uses of these elastomers are varied. For butyl rubber, the majority of these applications are for the rubber without halogenation, whereas more than half of butyl

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Synthetic rubber consumption per capita has slacked off

Kilograms per capita	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
U.S.	7.8	9.1	8.3	11.0	11.3	11.3	10.0	9.2	13.9	11.6
Canada	7.4	8.6	8.1	9.6	8.6	8.8	8.8	7.9	8.1	8.5
U.K.	3.2	3.9	4.5	5.3	5.5	5.7	5.8	4.7	5.0	5.9
West Germany	6.4	6.4	7.1	7.2	6.9	7.0	7.1	5.8	6.6	7.2
France	5.0	5.6	5.3	5.8	5.5	5.5	5.4	5.2	5.9	5.9
Mexico	1.7	1.7	1.6	1.5	1.4	1.4	1.4	1.2	1.4	1.0
Brazil	1.5	1.6	1.9	1.8	1.9	1.8	1.8	1.6	1.6	1.5
Japan	8.7	7.2	7.6	7.1	6.4	6.1	5.8	5.2	5.6	6.6
Taiwan	3.8	4.1	5.5	5.1	4.1	3.6	2.8	1.7	1.8	2.4
South Korea	2.8	3.5	3.7	3.3	3.1	2.3	1.7	1.7	1.3	1.1
China	0.15	0.11	0.12	0.10	0.09	0.08	0.06	0.06	0.06	0.06
Eastern Europe	5.9	6.0	6.7	6.7	6.5	6.1	5.7	5.6	5.0	4.5
WORLD AVERAGE	1.8	1.9	1.9	2.1	2.0	2.0	1.9	1.8	1.8	1.9

Source: International Institute of Synthetic Rubber Producers

used in tires is either chlorinated or brominated to improve its compatibility with other synthetic elastomers. The nontire miscellaneous uses of polyisoprene are most often as a replacement for natural rubber; other uses of significance are in mechanical goods such as automotive and medical applications and in footwear.

Nontire uses could be the key to success for EPDM, often cited as the fastest growing of the major-volume synthetic elastomers. A 21% worldwide growth is forecast by IISRP, excluding communist countries, between 1983 and 1988, representing a rise from 343,000 metric tons to 416,000 metric tons. This consumption will be well up from the recent historical low set in 1982 at about 279,000 metric tons.

About 10% of U.S. consumption of EPDM now goes into tires, especially as the elastomer in the white sidewall stripe material. Other automotive uses include hoses, weather seals, grommets, and the like, which take another 15% of the elastomer. These and smaller automotive uses of polymers and elastomers modified with EPDM bring the total of all automotive uses of EPDM to about a third of its total consumption, perhaps a bit less.

One of the faster growing applications of ethylene-propylene elastomers, both the copolymer and the terpolymer with a nonconjugated diene, is in modifying thermoplastics, particularly polypropylene. Many variations of polymer modification and of manufacture of thermoplastic olefin elastomers are done to meet end product requirements. This seems to be a fertile field for new product development with large and small companies working in it. Growth rates for the near term in these areas could hold in the 10% annual rate, although the base is small.

The most talked about growing use of EPDM is in single-ply roofing. This use could reach 30,000 to 35,000 metric tons of EPDM in 1985, up from a third of this amount in 1981. EPDM's resistance to ozone and to general weathering makes it the dominant elastomer in this use. Other advantages helping its rapid growth of 20% or more annually in this use are its relatively lighter weight if compared to builtup roofs, ability to be used over heat-sensitive insulation materials such as polystyrene or polyurethane, and lower installation costs.

Because of the current diverse uses and expected future uses, more development money goes into EPDM technology than into other major-volume elastomers. This investment could lead to more investment in capacity if estimates of growth hold up.

Of all the synthetic rubbers, polychloroprene (neoprene) seems to be in the most trouble. In the U.S., production in 1983 fell slightly from 1982, down 3.2% to 115,000 metric tons, making it the only major-volume rubber to have smaller production in 1983 than in 1982. Exports, which account for 30 to 40% of U.S. production, fell more than 10% last year, causing the decline. U.S. consumption rose nearly 20% in 1983.

Although use of polychloroprene in tires is negligible, about a third

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of U.S. consumption goes to automotive uses by being fabricated into belts, wire covering, and the like. Nonautomotive wire and cable uses take a quarter of consumption as does manufacture of adhesives.

No major use development seems to be coming for polychloroprene, so consumption forecasts are for small growth of 1 to 2% annually. Prices for the elastomer are relatively high. Therefore the cost of using polychloroprene must be weighed against its very desirable properties of resistance to ozone and weathering, high strength, and high resilience. Cost and competition from other materials for use in severe service make the outlook for polychloroprene that of slow growth for the longer term.

Nitrile elastomers, another of the older synthetic rubbers, also face slow going. Growth worldwide, excluding communist countries, will be modest, perhaps 3% annually over the next five years. Production in the U.S. in 1983 totaled 55,000 metric tons, well down from the previous high set in 1974 of 88,000 metric tons.

Prices for nitrile elastomers run around $1.00 per lb, making it prohibitively expensive unless its properties can't be supplied by another product. Its high resistance to oils makes it desirable in automotive uses such as hoses and gaskets.

A large number of specialty elastomers are made in varying quantities, with a total of somewhat more than 100,000 metric tons a year. Production and consumption data for these materials are meager, especially since butyl and polyisoprene statistics now are grouped into the "all other" category. The more important specialty elastomers in terms of estimated production volumes are the urethanes, silicones, chlorosulfonated polyethylenes, and polysulfides.

Although new developments in production and use of the specialty and other low-volume synthetic rubbers will get the most attention, the workhorse of the rubber business will continue to be SBR. More than half of the worldwide consumption of synthetic rubber will be SBR and about a third of all rubber consumption will be SBR. As the major tire rubber, SBR, too, will lead the resumption of growth in the synthetic rubber industry.

The pace of growth will be nothing like it was during the 1960s and the early 1970s, but it could become steadier than that of the past 10 years. For most rubbers, sufficient capacity exists to meet expected growth, thereby reducing investment capital needs for the rest of this decade. Supplies of monomers will be adequate unless another major stoppage of world oil supply occurs. These factors then could make the rest of the 1980s a time of better profit for well-managed companies in the synthetic rubber industry. □

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